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SEWAGE RECLAMATION BY SPREADING BASIN INFILTRATION

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SANITARY ENGINEERING DIVISION

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PAPERS

SEWAGE RECLAMATION BY SPREADING BASIN
INFILTRATION

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SYNOPSIS

To study the feasibility of recharging the ground water with effluent from sewage treatment plants, experimental spreading basins were established in Los Angeles County, Calif. Two locations were used to evaluate the effect of climate, soil characteristics, type of spreading fluid on the suitability of the percolated product, and rates of infiltration.

It was found that Biochemical Oxygen Demand (B.O.D.) and Dissolved Oxygen (D.O.) content of the sewage effluent profoundly influenced the quality of the fluid sampled at various depths in the soil beneath the spreading basin. Additional data are given concerning the chemical and bacteriological data observed at the two test sites. The effect of algae in replenishing the oxygen in the basins is also discussed.

Conclusions relating to the successful operation of these types of basins are given and are based on an analysis of the experimental data.

INTRODUCTION

The replenishment of the ground-water supply in Los Angeles County is an increasingly urgent project. Almost 66%³ of the water used in the area comes from the underground supplies, and the accelerated industrial and agricultural demands have resulted in a serious depression of the water table. Thus, problems such as salt water intrusion, local or spot shortages, increased pumping costs, and the need for deeper wells, have become evident.

The reclamation of sewage effluents has long been recognized as a means of conserving the water resources of arid regions. In fact, cesspools and septic

Note.—Written comments are invited for publication; the last discussion should be submitted by March 1, 1952.

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³ "South Coastal Basin Investigation; Overdraft on Ground Water Basins," *Bulletin No. 53*, State of Calif. Dept. of Public Works, Div. of Water Resources, 1947.

tanks in Los Angeles County have been returning sewage effluent to the ground water for many years. Realizing the possibilities of large-scale reclamation, the Board of Supervisors of Los Angeles County, on January 27, 1948, appointed a Board of Engineers to investigate the feasibility of conserving water reclaimed from sewage. In the course of the investigation the Los Angeles County Flood Control District constructed test spreading basins to percolate effluents from the Whittier, Calif., and Azusa, Calif., sewage treatment plants.

Scope of the Experiments.—The test spreading basins presented areas of known dimensions into which precisely measured amounts of fluids could be introduced and in which percolation rates could be closely determined. Therefore, experimental studies were made to consider the following problems:

1. The development of a method of obtaining samples suitable for testing the bacteriological, chemical, and biochemical characteristics of fluids infiltrated through the soils;
2. To make an evaluation of the hydrologic characteristics of earth basins treated with sewage effluents;
3. To make an evaluation of operating difficulties, such as odors that may arise from spreading sewage effluents;
4. To determine the dissolved solids increment in the cycle linking potable water to sewage effluent, and the probable effect of the infiltration of such effluent into the ground waters of the test area;
5. To make an evaluation of infiltration through earth beds as a means of removing the bacterial pollution of the spread waters.

The Whittier test program was undertaken as an exploration into the feasibility of reclaiming sewage effluent. After the encouragement of satisfactory performance of the spreading basin at Whittier, the percolation studies were continued at a second location at Azusa in order to evaluate the results that might be obtained under varying conditions of operation.

This paper is divided to conform with the chronological performance of infiltration studies. The discussion of the first installation at Whittier follows, with the Azusa data forming the second part of the paper.

TESTS AT THE WHITTIER SEWAGE TREATMENT PLANT

The Experimental Test Basin.—A small experimental spreading basin was constructed near the Whittier Sewage Plant. The 26-ft by 50-ft inside dimensions provided 0.028 acres of wettable area. The basin was excavated by removing 1 ft of cover from the surface of the ground; this earth was then built into levees approximately 3 ft high. The fluid to be spread was brought into a stand pipe from which it entered a weir box and passed through a V-notch weir into the basin. A hook gauge was installed in the weir box for measuring the rate of flow into the test basin, and, in addition, a continuous stage recorder took 24-hr records. A similar 24-hr record was made of the elevation of the fluid in the test basin. The fluids spread included potable well water and sewage effluents from the Whittier Plant. This plant is a 10-yr-old trickling filter plant, operating on an average daily loading of 2.8 mgd and normally delivering its effluent to irrigation or to an open water

course. The sewage plant process varies from the usual only in the fact that the raw sewage is aerated before primary sedimentation.

Sampling Pans.—Samples of the percolated fluid were obtained in open-top, water-tight collection pans buried at 1-ft intervals from 4-ft to 7-ft depths

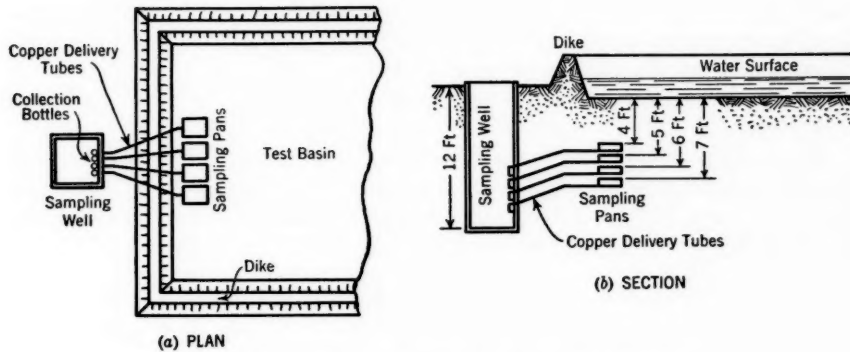


FIG. 1.—PLACEMENT OF SAMPLING PANS IN WHITTIER TEST BASIN

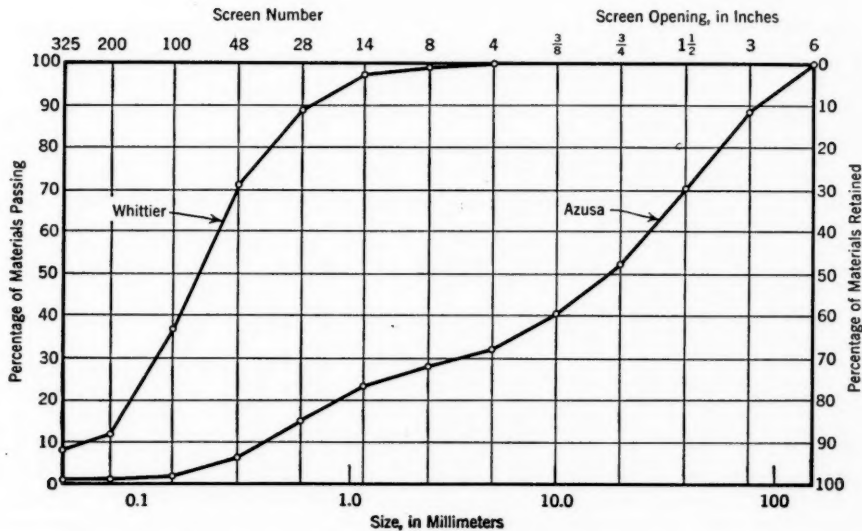


FIG. 2.—ANALYSIS OF TEST BASIN SOILS BEFORE SPREADING

below the floor of the basin. Details as to the placement and construction of the sampling pans are outlined in Fig. 1. Originally the pans at the 4-, 5-, and 6-ft levels were filled with finer sands, but difficulties with permeability led to the adoption of the coarser material originally employed in the pan at the 7-ft level as shown in Fig. 1.

Subbasin Conditions.—The type of soil upon which the Whittier Basin was constructed consists of a top layer of 4.5 ft of sandy loam varying from fine to coarse as the depth increases. From 4.5-ft to 7-ft depth there is a sand stratum that increases in coarseness in proportion to depth. Below the 7-ft level the material is finer and test-well logs show red clays at a depth of about 14 ft. The effective size of the soil, as determined by wet sieve analysis, was approximately 0.044 mm from the surface to a depth of 4.5 ft. The effective size was 0.052 to 0.092 mm from 4.5-ft depth to a depth of 10 ft. The uniformity coefficient varied between 3.42 and 5.0. Fig. 2 shows these soil characteristics.

For the purpose of determining the characteristics of the soil strata beneath the test basin and for observing the position of the water table, 12 wells were driven to a depth of 12 ft to 14 ft. At no time during the test did the water table rise to a level closer than 3 ft below the lowest collection pan.

DATA OBTAINED FROM THE WHITTIER TESTS

Plant Data.—The results of a number of composite and grab samples taken at the Whittier Sewage Plant are listed in Table 1. The average B.O.D. of the unchlorinated secondary effluent was 14 ppm.

Hydraulic Data.—Several test runs, using various fluids, were made in the basin prior to a final 7-day test using a single fluid. The interval between test runs was such that the basin could be completely dewatered and runs

TABLE 1.—SUMMARY OF DATA IN PARTS PER

Date	Fluid	BASIN INFLOW					BASIN EFFLUENT					TEST WELL FOOT		
		B.O.D.	D.O.	Chlorine	S.S. ^b	T.S. ^c	B.O.D.	D.O.	Chlorine	S.S. ^b	T.S. ^c	B.O.D.	D.O.	Chlorine
(1)	(2) ^a	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
12- 6-48	Cl. Sec	43	5.24	81	20	408	...	...	...	...	...	<0.5	4.04	112
12- 8-48	Cl. Sec	...	...	...	...	...	...	...	...	...	...	...	...	...
12- 8-48	Cl. Sec	...	...	...	...	...	...	...	...	...	...	...	...	...
12- 9-48	Uncl. Sec	4	4.40	92	52	560	...	7.52	...	...	...	...	...	...
12-10-48	Uncl. Sec	10	3.96	142	50	622	6	5.44	71	0+	480	...	...	...
12-11-48	Uncl. Sec	...	...	...	...	...	...	...	...	...	...	...	...	...
12-14-48	Water	0.5	0.16	107	0	965	<0.5	5.16	107	16	967	<0.5	...	122
12-17-48	Uncl. Sec	4	5.64	89.5	20	542	2.5	7.04	75.8	32	462	<0.5	6.20	68
12-18-48	Uncl. Sec	6.1	3.12	58.5	12	512	4.6	6.12	82.8	52	548	<0.5	6.00	92.6
12-19-48	Uncl. Sec	7.3	5.60	63.1	48	482	6.1	6.20	86.0	40	558	<0.5	...	98.5
12-20-48	Uncl. Sec	6.3	4.88	57.9	48	456	2.3	5.60	67.9	76	492	<0.5	5.52	60.6
12-21-48	Uncl. Sec	8.6	5.88	76.1	16	588	3.5	5.24	86.3	...	504	<0.5	5.24	86.3
12-22-48	Uncl. Sec	7.7	1.64	88.3	32	636	4.6	6.80	81.2	12	572	<0.5	5.24	68.6
12-23-48	Uncl. Sec	8.5	2.67	66.1	60	560	3.4	4.68	91.2	4	580	<0.5	5.36	81.3

^a In this column, Cl. Sec denotes chlorinated effluent of secondary treatment process and Uncl.

prior to the final 7-day test did not exceed 28 hr in length. Potable water, chlorinated secondary effluent, and unchlorinated secondary effluent were used during the short tests; but only unchlorinated secondary effluent was used during the 7-day run. A fluid depth of 0.5 ft was maintained in the basin throughout most of the test, and the rate of infiltration varied between the upper limit of 460,000 gal per acre per day to 582,000 gal per acre per day

for chlorinated secondary effluent and the lower limit of 236,000 gal per acre to 378,000 gal per acre per day for the unchlorinated effluent. The effect of evaporation was ignored in the hydraulic measurements.

The final run indicated the feasibility of spreading the Whittier unchlorinated secondary effluent on the test soil at an average percolation rate of 0.5 cu ft per sec per acre or 323,000 gal per acre per day (0.99 ft per day vertical travel) without sealing the test basin or causing odor nuisances. The average (0.5 cu ft per sec per acre) percolation rate developed compares favorably with prior experience.⁴

BACTERIOLOGICAL DATA

The Most Probable Number of Coli-Aerogenes Bacteria in Test Fluids.—The sanitary quality of water is conveniently measured by the determination of the Most Probable Number (MPN) of coli-aerogenes bacteria per cc of sample. The unchlorinated secondary effluent from the Whittier Plant was grossly polluted, having a MPN of 110 + coli-aerogenes bacteria per cc in all samples from the basin.

It is important to note that, after 304 hr of spreading polluted secondary effluent (168 hr continuously) at an average rate 0.5 cu ft per sec per acre, there was no evidence of coli-aerogenes pollution in the percolated sewage samples. The tabular data show minor contamination in several of the percolated samples, but this is probably due to outside pollution resulting when the 4-ft depth collection pan was dug up for inspection. Also, it was necessary to

MILLION—WHITTIER, CALIF., SPREADING BASIN

—FOUR-LEVEL		TEST WELL—FIVE-FOOT LEVEL					TEST WELL—SIX-FOOT LEVEL					TEST WELL—SEVEN-FOOT LEVEL				
S.S. ^b	T.S. ^c	B.O.D.	D.O.	Chlorine	S.S. ^b	T.S. ^c	B.O.D.	D.O.	Chlorine	S.S. ^b	T.S. ^c	B.O.D.	D.O.	Chlorine	S.S. ^b	T.S. ^c
(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
48	816	<0.5	5.80	137	32	944	<0.5	3.80	122	22	1,020	<0.5	7.24	117	18	672
...	...	...	...	...	...	...	...	5.12	...	...	...	...	5.64	...	...	...
...	...	<0.5	8.80	152	...	...	<0.5	3.64	112	...	...	<0.5	6.60	122	8	600
...	...	...	...	...	...	...	<0.5	...	107	...	1,032	<0.5	5.64	122	...	432
...	...	...	...	...	...	...	<0.5	...	103	...	1,054	...	7.04	93	0	584
20	1,020	...	...	...	...	...	...	...	...	...	...	<0.5	5.52	99	4	663
0	988	...	...	...	...	...	...	...	...	...	...	<0.5	6.28	101	0	854
0	888	...	...	...	...	...	...	...	...	...	...	<0.5	4.88	89.5	0	780
0	700	...	...	...	...	...	...	...	...	...	...	<0.5	5.04	84.8	0	710
0	534	...	...	...	...	...	...	...	...	...	...	<0.5	6.48	94.4	0	660
0	504	...	...	...	...	...	<0.5	...	82.8	0	904	<0.5	6.00	73.6	0	528
0	708	...	...	...	...	...	...	...	...	...	...	<0.5	6.00	87.4	0	584
0	504	...	...	...	...	...	<0.5	...	91.4	0	904	<0.5	6.04	86.2	0	610

See denotes unchlorinated effluent of secondary treatment process. ^b Suspended solids. ^c Total solids.

collect samples of percolated fluid slowly in sterile bottles open to the atmosphere for several hours.

Soil samples from a test hole dug in the basin at the conclusion of the tests seemed to confirm the above findings, for the soil showed coli-aerogenes

⁴ "Filtering Materials for Sewage Treatment Plants," *Manuals of Engineering Practice No. 13*, ASCE, New York, N. Y., 1937, p. 16.

pollution ranging from 100 to 6,000 organisms per cc at the surface to 40 per cc at the 3-ft depth, and negative results for coli-aerogenes bacteria below the 3-ft level.

CHEMICAL AND PHYSICAL DATA

Dissolved Oxygen Content and Biochemical Oxygen Demand.—The D.O. content of the treated effluents received at the test basin averaged 4.2 ppm. After exposure to the atmosphere the D.O. had increased to an average of 5.95 ppm at the far end of the basin, and the samples of percolated fluid obtained at the 7-ft level averaged 5.6 ppm. The B.O.D. of the spread waters varied inversely with the D.O., and the inflowing sewage effluents averaged 6.9 ppm of B.O.D. and percolated fluid at the 7-ft depth averaged less than 0.5 ppm B.O.D.

These D.O. and B.O.D. values, when combined with the bacteriological results, seem to be of great importance in formulating an explanation of the mechanisms involved in the purification of the percolated sewage.

From these data it was postulated that the purification process was analogous to trickling filter operation. As long as an adequate D.O. content was maintained, aerobic zoogloal bacteria would develop in and on the surface of the basin and perhaps to some depth in the soil. These would act, as in trickling filters, to quickly adsorb the organic matter from the percolating fluids and, in addition, form a mechanical filter mat where bacteria would be trapped and gradually die out.

From the experimental results it was empirically decided that a satisfactory percolating fluid should have 0.5 ppm of D.O. and less than 0.5 ppm of B.O.D. at the sampling pan level that was to be used for control.

The B.O.D. of the soil samples obtained at the end of the tests seemed to confirm this hypothesis. A substantial B.O.D. was obtained in the top soil, but at the 4-ft sampling point this B.O.D. decreased to less than 0.5 ppm and no B.O.D. was found at lower depths.

Suspended Solids Present in the Percolated and Unpercolated Effluents.—The quantity of suspended solids in the fluid introduced into the spreading basin influences the percolation rate. These solids settle initially and form a mat upon the surface of the bed, acting to seal off the percolation of the fluid. In addition, the organic matter present in the mat undergoes decomposition. Hence, in order to maintain aerobic conditions, the B.O.D. of the organic matter must be satisfied.

If aerobic conditions are maintained in the bed, decomposition of the organic matter in the suspended solids mat is apparently quite rapid. In the experimental test basin a relatively constant percolation rate was reached. However, inorganic materials and relatively stable undigested organic matter, together with zoogloal slimes, algae, and so forth, in time accumulate within the surface soil and necessitate drying and scarifying of the surface of the basin.

If the D.O. to B.O.D. relationship is such that no D.O. is found at the test level and a B.O.D. in excess of 0.5 ppm is obtained, the solids mat builds up quite swiftly, reducing the percolation rate and forcing early drying and scraping of the basin surface. Furthermore, the Azusa tests indicate that

when these conditions prevail anaerobic environment exists and coli-aerogenes bacteria are carried by the percolating fluid.

The suspended solids content of the unchlorinated effluent entering the Whittier test basin averaged 34 ppm, but at all sampling depths the percolated fluid showed an absence of suspended solids.

The pH, total solids, and other characteristics of the Whittier sewage were found to be normal for domestic sewage in the southern California area (see Table 1).

Temperature and Weather Data.—The studies described were made between the dates of November 29, 1948, and December 23, 1948. During this period the temperature of the influent into the basin ranged from 48° F to 72° F and the basin temperature ranged between 43° F and 71° F. The average air temperature during December, 1948, was 53.4° F. Thus the tests were made during a period when temperatures favored oxygen absorption and minimum odors and biochemical action was at a low rate. No nuisance arose from the operation of the bed, and the loading was such that sparkingly clear effluent of good sanitary quality was produced at the 7-ft level.

The experimental data from the Whittier test is summarized in Table 1 and Fig. 3.

TEST AT THE AZUSA SEWAGE TREATMENT PLANT

The Experimental Test Basin.—A second experimental spreading basin was established adjacent to the Azusa Sewage Treatment Plant in order to: (a) Check the results of the original Whittier Studies; (b) evaluate the effect of the coarser soils upon the spreading phenomenon; (c) evaluate the results of spreading in a larger basin; (d) determine the effects of continuous long-term spreading operations throughout a period of more than 60 days; (e) observe the effects of warm weather operation of the beds with emphasis on odor development; (f) determine the dissolved mineral pickup in the normal domestic use of water as a refuse carrier and from this to estimate the number of cycles of possible reuse of the reclaimed water; (g) test the effect of spreading effluents with varying values of B.O.D.; (h) observe the effect of algae action upon the spreading phenomena; and (i) evaluate the effects of an anaerobic environment on the spread fluid.

At the Azusa treatment plant an unused percolation basin was reconstructed to provide a bed 50 ft by 70 ft with 3-ft fluid depth. The inflow structure and flow and depth recording mechanisms were similar to those employed at the Whittier site.

The Azusa treatment plant is a 9-yr-old trickling filter plant handling primarily domestic sewage and operating at the designed capacity of 475,000 gal of raw sewage a day. Unusual features in plant operation include: (1) The primary settled sewage is chlorinated before discharging onto the trickling filter; and (2) the plant is operated by one man with a minimum of maintenance difficulties.

Throughout the entire operating history of this plant the effluent has been disposed of in percolation basins. These basins are operated by discharging the total final effluent flow of the plant into a single basin for a 7-day period,

after which it is diverted to another basin. The flooded basin is allowed to dry and is then reused. In time a mat of inorganic and organic matter builds up on the bottom of the basin reducing a percolation rate and necessitating the removal of a few inches of top soil in order to restore the percolation rate.

The experimental basin was similarly operated although the amount of fluid spread was closely controlled. The period of application was for much

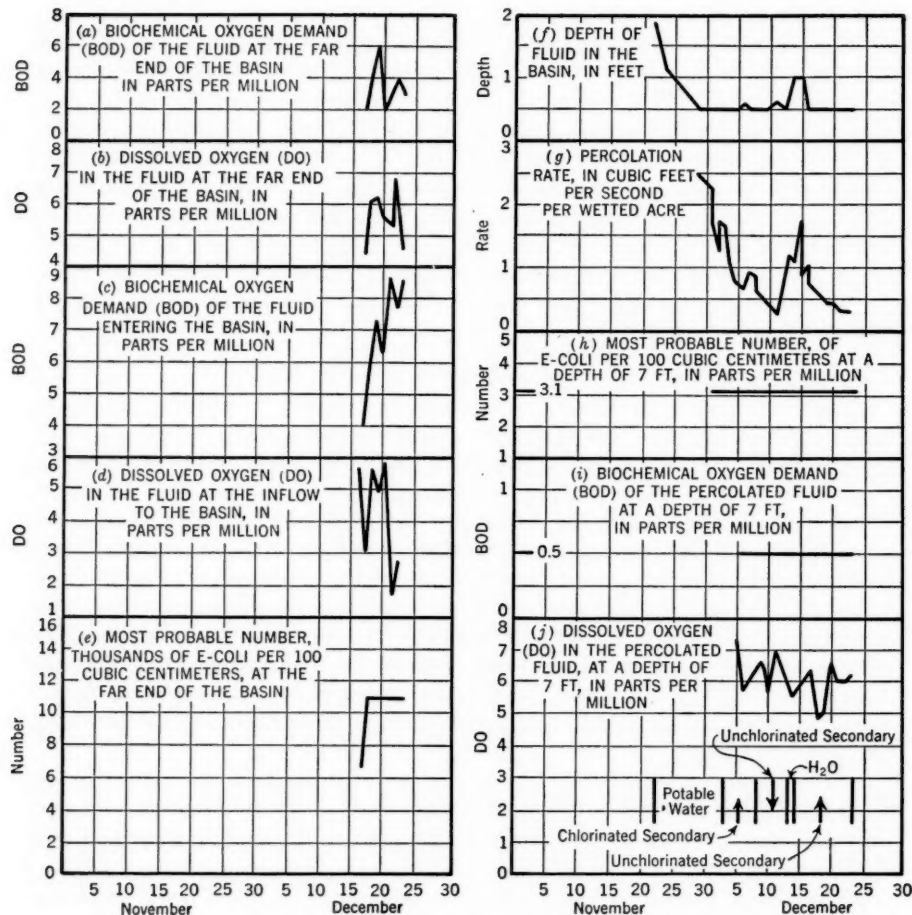


FIG. 3.—OPERATIONAL RECORD, WHITTIER, CALIF., SPREADING BASINS

longer than 7 days, and for a one-week period an admixture of primary and secondary effluents was spread.

Sampling pans similar to those developed during the Whittier tests were used, with the recommended filling material graded from $\frac{1}{4}$ -in. gravel at the bottom to $\frac{1}{30}$ -in. sand at the top. Only two sampling points were used, with 3 pans placed at the 7-ft depth to facilitate rapid sampling, and one

placed at the 2½-ft depth to provide a check on the rapidity of purification of the percolating fluids. As at Whittier, a sampling well was employed to obtain samples of the percolated fluids.

The Azusa spreading basins are underlain by coarse sand and gravel. A test hole dug to the depth of 10 ft indicated an effective size varying between 0.36 mm and 0.45 mm, with a uniformity coefficient between 40.5 and 91.0 (see Fig. 2). The log of the Glendora Consolidated Irrigation Company Vosburg Well, located adjacent to the sewage plant, shows the underground formation to consist of gravel and boulders to a depth of 414 ft. The water table stands at depths exceeding 200 ft below the ground surface, and on September 1, 1949, was at 264 ft.

DATA OBTAINED FROM THE AZUSA TESTS

Plant Data.—Throughout most of the testing period a supply of D.O. was present in the sewage at all points in the treatment process including the plant influent. The secondary effluent D.O. varied from 1.87 ppm to 3.68 ppm. The secondary effluent B.O.D. averaged 33 ppm. A listing of the complete test data can be found in Tables 2 and 3.

Hydraulic Data.—The Azusa reclamation tests started with the spreading of final treated effluent for 5 days. After this time a mixture of primary and secondary effluents was introduced into the spreading basin for a period of 1 week. The test basin was then returned to the spreading of final treated effluent. After 1 month of continuous percolation the basin was dried up. After a subsequent 1-week drying period soil samples were taken and secondary effluent was again percolated for a 2-month continuous period.

By the admixture of primary effluent to the final effluent a fluid with 100 ppm of B.O.D. was obtained. When this fluid was introduced into the basin to a depth of 2 ft, the available oxygen supply was quickly depleted and B.O.D.'s as high as 24 ppm were obtained at the 7-ft level. A suspended solids content was also found in the percolated fluid at all test levels, and the percolation rate dropped sharply. The percolation rate for this first 30-day test started at approximately 10 cu ft per sec per wetted acre, but at the end of the period it had dropped to 0.9 cu ft per sec per wetted acre. During a continuous run of 2 months the predominant percolation rate was 0.6 cu ft per sec per wetted acre although the rate fluctuated from 0.19 cu ft per sec per wetted acre to greater than 2 cu ft per sec. The fluid depth averaged 2 ft.

The extended Azusa test indicated that in a soil with the characteristics shown in Fig. 2 a fluid with 33 ppm of B.O.D., 70 ppm of suspended solids, and 2.2 ppm of D.O. would achieve a percolation rate (0.6 cu ft per sec per acre) that would remain relatively constant for a long period of time; and soil of this nature would deliver an effluent of a satisfactory sanitary quality that would cause no odor or operating difficulties. It is of interest to note in Fig. 4 the inverse variation in percolation rate to the observed D.O. content as the bed condition changed from the time at which dissolved oxygen and a B.O.D. of less than 0.5 ppm were found in the percolated fluid at the 7-ft level to the time when no D.O. and a substantial B.O.D. existed, and then back to the original condition.

The fine Whittier soil gave a maximum percolation rate that could be varied little, if at all, by measures such as increasing the head on the basin whereas the percolation rate in the coarse soil of the Azusa basin could initially be varied by changing the head. Thus, practically, the organic loading on the Whittier basin could be controlled by the B.O.D. alone, but both the initial percolation rate and the B.O.D. were possible variables at Azusa. However,

TABLE 2.—MINERAL ANALYSES IN PPM—AZUSA SPREADING TEST

Sample	Date	COMPONENT										pH	
		Sodium (Na ⁺)	Potassium (K ⁺)	Calcium (Ca ⁺⁺)	Magnesium (Mg ⁺⁺)	Sulfate (SO ₄ ⁻)	Bicarbonate (HCO ₃ ⁻)	Chloride (Cl ⁻)	Nitrate (NO ₃ ⁻)	Ammonia (NH ₃)	Nitrogen Organic (N)		Boron (B)
(a) Azusa Plant.....	5-19-49												
Raw Influent.....		61.0	12.4	107.6	21.6	19.8	369	61.5	0.1	34.6	14.5	0.5	7.1
Primary Effluent....		64.0	13.6	118.1	18.6	3.3	...	79.1	0.08	33	12.7	<0.1	7.1
Trickling Filter Effluent.....		64.9	15.6	108.8	36.0	42.8	153	68.6	1.4	5.4	7.8	0.2	7.0
Influent Percolation Basin.....		64.0	15.6	123.2	21.8	47.3	153	67.0	2.0	4.6	6.4	0.2	7.0
Far End of Percola- tion Basin.....		58.0	20.8	80.1	40.8	42.4	139	67.6	1.6	5.6	6.3	0.1	7.0
(b) Azusa Water System	5-17-19												
Azusa Top Water...		9.6	3.1	54.4	14.4	27.2	206	11.2	0.2	...	...	0.1	7.4
Well No. 1.....		9.3	3.1	52.0	14.6	28.0	206	9.7	0.56	...	...	0.1	7.3
Well No. 2.....		...	...	...	...	...	205	7.6	...	...	...	...	7.3
Well No. 3.....		9.2	4.5	48.0	13.2	22.6	193	7.6	1.2	...	...	0.2	7.3
Well No. 4.....		19.6	1.6	76.8	16.4	37.4	283	21.3	1.6	...	...	0.1	7.3
Azusa Plant.....	6-17-49												
Raw Influent.....		82.1	12.4	...	...	...	383	103.7	0.13	29	7.7	1.3	...
Primary Influent....		61.0	12.4	...	...	...	390	51.8	0.8	23.4	9.1	1.6	...
Trickling Filter Effluent.....		62.6	13.1	...	...	...	200	45.8	0.4	3.2	3.8	<0.1	...
Influent Percolation Basin.....		64.8	12.8	...	...	...	193	45.8	0.4	5.6	3.9	1.7	...
Far End of Percola- tion Basin.....		64.0	13.3	...	...	...	176	50.8	0.28	0	7.3	1.2	...
(c) Azusa Plant.....	6-20-49												
Influent Percolation Basin.....		...	...	...	...	...	220	62.8	0.8	9.4	8.0	...	...
Far End of Percola- tion Basin.....		...	...	...	...	...	194	41.6	1.0	3.9	5.2	...	...
Percolation Fluid 2½ ft Depth.....		53	12.2	102.8	33	56.4	205	40.5	1.6	0.3	2.4	0.5	...
Percolation Fluid 7 ft Depth.....		53	12.5	102.4	33	48.1	228	43.7	0.4	0.4	2.4	0.3	...
(d) Metropolitan Water District.....	1947 to 1948	190	3	30	14	319	99	98	0.01	...	...	0.14	...

after continuous spreading over a considerable period a surface mat layer is built up in any type of soil. Hence this interface becomes a controlling factor in the ultimate rate of percolation regardless of the soil coarseness.

Recommended Test Basin Operations.—The experimental work and available data do not warrant conclusions as to the operation of the beds. It is probable that operational schedules would have to be fixed for each soil and each spreading location. In the Los Angeles area the Azusa sewage plant

TABLE 3.—SUMMARY OF DATA—AZUSA, CALIF., SPREADING BASIN

Location	Time	B.O.D. (ppm)	D.O. (ppm)	MPN coli- aerogenes (per cc)	pH	Tem- perature (degrees F)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(a) JULY 1, 1949						
Inflow to basin.....	.....	38.3	2.80	.....	.....	.....
Far end of basin.....	.....	27.4	1.60	700	.....	.....
Percolated fluid {2½-ft depth.....	.....	2.0	0.75	2.40	.....	.....
7-ft depth.....	.....	<0.5	0.30	{0.62 2.40	.....	.....
(b) JULY 3, 1949						
Percolated fluid {2½-ft depth.....	.....	.....	.....	70	.....	.....
7-ft depth.....	.....	.....	.....	70	.....	.....
(c) JULY 5, 1949						
Inflow to basin.....	.....	.....	2.4	.....	.....	.....
Far end of basin.....	.....	.....	2.4	.....	.....	.....
Percolated fluid {2½-ft depth.....	.....	.....	1.6	24	.....	.....
7-ft depth.....	.....	.....	0	{7 2.4	.....	.....
(d) JULY 7, 1949						
Inflow to basin.....	.....	.....	2.0	.....	.....	.....
Far end of basin.....	.....	.....	3.6	.....	.....	.....
Percolated fluid {2½-ft depth.....	.....	.....	1.6	0.031	.....	.....
7-ft depth.....	.....	.....	0	0.031	.....	.....
(e) JULY 11, 1949						
Inflow to basin.....	.....	81.9	.....	.....	.....	.....
Far end of basin.....	.....	14.5	.....	.....	.....	.....
Percolated fluid {2½-ft depth.....	.....	4.3	.....	.....	.....	.....
7-ft depth.....	.....	1.4	.....	.....	.....	.....
(f) JULY 14, 1949 PERCOLATION RATE = 0.51 CU FT PER SEC PER ACRE						
Inflow to basin.....	0945	.....	2.4	.....	7.3	78
Far end of basin.....	0855	.....	5.9	.....	7.1	76
Percolated fluid {2½-ft depth.....	1120	.....	0.9	0.06	7.3	76
7-ft depth.....	1010	.....	0	0.03	7.2	74
(g) JULY 19, 1949 PERCOLATION RATE = 0.53 CU FT PER SEC PER ACRE						
Inflow to basin.....	1125	62.8	3.32	.....	7.4	78
Far end of basin.....	1110	14.8	19.20	.....	8.0	85
Percolated fluid {2½-ft depth.....	1100	0.7	0.28	.....	7.2	78
7-ft depth.....	1100	<0.5	0.20	.....	7.2	77
(h) JULY 21, 1949 PERCOLATION RATE = 0.73 CU FT PER SEC PER ACRE						
Inflow to basin.....	0900	.....	4.0	.....	7.5	77
Far end of basin.....	0855	.....	7.0	.....	7.6	76
Percolated fluid {2½-ft depth.....	0825	.....	0.2	.....	7.2	76
7-ft depth.....	0835	.....	0	.....	.....	.....

TABLE 3.—Continued

Location	Time	B.O.D. (ppm)	D.O. (ppm)	MPN coli- aerogenes (per cc)	pH	Tem- perature (degrees F)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(i) JULY 26, 1949 PERCOLATION RATE = 0.73 CU FT PER SEC PER ACRE						
Inflow to basin.....	0945	29.30	2.88	120 +	7.2	76
Far end of basin.....	0925	36.10	2.80	0.62	7.3	73
Percolated fluid (2½-ft depth.....	0820	0.77	0	0.23	7.2	75
Percolated fluid (7-ft depth.....	0850	0.50	0	0.23	7.2	75
(j) JULY 28, 1949 PERCOLATION RATE = 0.63 CU FT PER SEC PER ACRE						
Inflow to basin.....	0945	....	2.80	....	7.2	73
Far end of basin.....	0930	....	2.32	....	7.4	72
Percolated fluid (2½-ft depth.....	1040	....	2.38	0.23	7.2	74
Percolated fluid (7-ft depth.....	0915	....	0	1.03	7.2	75
(k) AUGUST 2, 1949 PERCOLATION RATE = 0.58 CU FT PER SEC PER ACRE						
Inflow to basin.....	1030	42.1	4.44	13	7.4	80
Far end of basin.....	1040	15.4	7.56	120 +	7.4	83
Percolated fluid (2½-ft depth.....	0850	6.3	0	0.61	7.2	77
Percolated fluid (7-ft depth.....	0855	9.9	2.20	0.29	7.2	76
(l) AUGUST, 4, 1949 PERCOLATION RATE = 0.58 CU FT PER SEC PER ACRE						
Inflow to basin.....	1030	....	5.48	24	7.4	82
Far end of basin.....	1015	....	9.56	24	7.6	83
Percolated fluid (2½-ft depth.....	0900	....	0	0.031 -	7.2	79
Percolated fluid (7-ft depth.....	0910	....	0.28	0.060	7.2	77
(m) AUGUST 9, 1949 PERCOLATION RATE = 0.63 CU FT PER SEC PER ACRE						
Inflow to basin.....	0935	28.7	4.20	120 +	7.2	76
Far end of basin.....	0945	18.0	5.20	120 +	7.4	75
Percolated fluid (2½-ft depth.....	0910	15.5	4.00	....	7.2	78
Percolated fluid (7-ft depth.....	0920	<0.5	0.88	0.62	7.2	76
(n) AUGUST 11, 1949 PERCOLATION RATE = 0.24 CU FT PER SEC PER ACRE						
Inflow to basin.....	0950	....	5.60	120 +	....	75
Far end of basin.....	1000	....	6.04	70	....	74
Percolated fluid (2½-ft depth.....	0925	....	3.36	....	....	75
Percolated fluid (7-ft depth.....	0940	....	0	0.06	....	78
(o) AUGUST 17, 1949 PERCOLATION RATE = 0.19 CU FT PER SEC PER ACRE						
Inflow to basin.....	1110	36.1	3.20	120 +	....	75
Far end of basin.....	1105	10.0	5.92	70	....	74
Percolated fluid (2½-ft depth.....	1030	0.8	0	0.031 -	....	76
Percolated fluid (7-ft depth.....	1045	10.1	0.08	0.031 -	....	75
(p) AUGUST 19, 1949 PERCOLATION RATE = 0.87 CU FT PER SEC PER ACRE						
Inflow to basin.....	1135	....	3.8	120	....	76
Far end of basin.....	1130	....	4.8	70	....	83
Percolated fluid (2½-ft depth.....	1115	....	0	0.060	....	80
Percolated fluid (7-ft depth.....	1120	....	0	0.031 -	....	77

TABLE 3.—*Continued*

Location	Time	B.O.D. (ppm)	D.O. (ppm)	MPN coli- aerogenes (per cc)	pH	Tem- perature (degrees F)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(q) AUGUST 23, 1949 PERCOLATION RATE = 0.53 CU FT PER SEC PER ACRE						
Inflow to basin.....	1020	9.4	3.60	120 +	....	....
Far end of basin.....	1030	7.1	1.56	120 +	....	....
Percolated fluid { 2½-ft depth.....	0945	6.4	0	0.06	....	77
7-ft depth.....	0955	1.3	0.68	0.06	....	77
(r) AUGUST 25, 1949 PERCOLATION RATE = 1.16 CU FT PER SEC PER ACRE						
Inflow to basin.....	0945	30.3	3.96	....	....	78
Far end of basin.....	0935	2.5	7.28	....	....	76
Percolated fluid { 2½-ft depth.....	0925	....	4.32	....	....	78
7-ft depth.....	0940	<0.5	0.64	....	....	76
(s) AUGUST 30, 1949 PERCOLATION RATE = 0.29-0.19 CU FT PER SEC PER ACRE						
Inflow to basin.....	0820	11.5	2.16	....	....	78
Far end of basin.....	0810	8.6	6.30	....	....	76
Percolated fluid { 2½-ft depth.....	....	....	....	....	....	....
7-ft depth.....	0825	<0.5	0.40	....	....	76
(t) SEPTEMBER 1, 1949 PERCOLATION RATE = 0.19-0.24 CU FT PER SEC PER ACRE						
Inflow to basin.....	1005	12.0	3.40	120 +	....	79
Far end of basin.....	1000	9.5	14.52	2.40	....	78
Percolated fluid { 2½-ft depth.....	....	....	....	....	....	....
7-ft depth.....	1020	1.9	2.48	0.03 -	....	76

has successfully used the procedure already mentioned, but the Polaris Flight Academy, at Lancaster, Calif., in a very tight soil, has used 1 day of filling followed by drying and harrowing of the basin. It seems certain, then, that local conditions such as soil, type of effluent, available land and equipment, and similar factors will decide operational procedure.

Bacteriological Data.—As in the Whittier tests, the secondary plant effluent entering the basin was grossly polluted, having 120 + coli-aerogenes organism per cc in the incoming fluid and at the far end of the basin. During the first week of the tests when only secondary plant effluent was spread the bacterial samples at the 7-ft depth were all negative. However, when the mixed primary and secondary effluents were added to the basin and anaerobic conditions developed in the soil, the coli-aerogenes counts in the percolated fluid at the 2½-ft and 7-ft levels rose to 1,200 + per cc. When secondary effluent was again used and aerobic conditions were gradually re-established, the coli-aerogenes counts dropped from 0.62 to 0.31 — per cc. This approaches drinking water quality. Thus it seems probable that when anaerobic conditions exist in the basin and in the soil, bacterial pollution can be carried to some depth by the percolating waters, but if aerobic conditions prevail the coli-aerogenes group is largely eliminated.

Soil samples were taken in two of the dry operating basins and at test basin before it was placed in use. These samples showed bacterial pollution ranging between 100 and 6,000 coli-aerogenes groups per cc in the surface soil to 40 per cc in the soil at the 3-ft depth. Below this depth no coli-aerogenes were found. However, when soil samples were taken after the test basin had become anaerobic, coli-aerogenes were found at all test depths. The following 2 months of aerobic operation gradually eliminated the bacterial contamination.

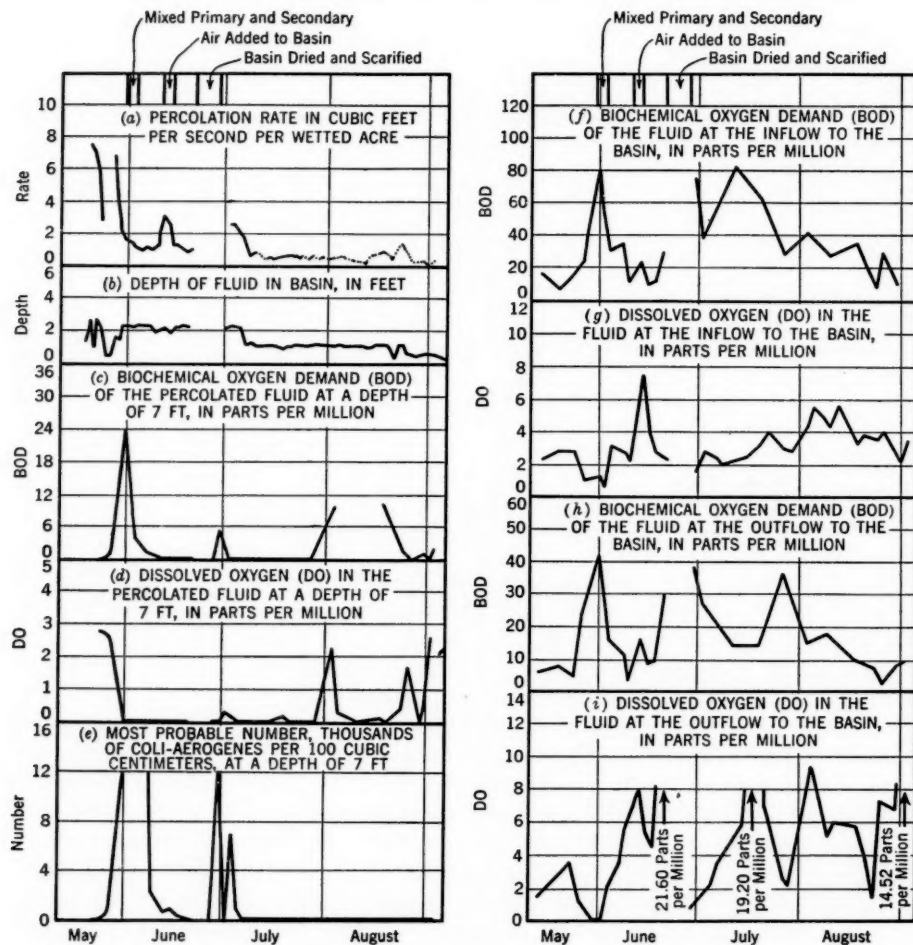


FIG. 4.—OPERATIONAL RECORD, AZUSA, CALIF., SPREADING BASINS

Bio-Chemical Data.—The D.O. content of the secondary effluent entering the basin averaged 2.2 ppm, and the D.O. of the percolated fluid at the 2½-ft depth averaged 1.5 ppm, and at the 7-ft depth the fluid was generally depleted of oxygen. When primary effluent was added to the basin no oxygen was found in any of the percolated samples.

The B.O.D. of the secondary effluent entering the test basin at Azusa averaged 23 ppm. At the overflow end of the basin the B.O.D. had dropped to 15 ppm, and at the 7-ft depth the percolated fluid showed a B.O.D. of 1.6 ppm. The mixture of primary and secondary effluents had a B.O.D. of approximately 100 ppm, and after this fluid had been added to the basin for 5 days, the percolated fluid at the 7-ft depth showed a B.O.D. of 25 ppm. When secondary effluent was again used, the B.O.D. at the 7-ft level gradually dropped to the 1.6 ppm average given previously.

CONCLUSIONS FROM DATA

From the bacterial, D.O., and B.O.D. data on the percolated fluid at the 7-ft level, certain conclusions can be drawn. The Whittier test basin had delivered a satisfactory effluent at the 7-ft level during the whole test period. Certain factors such as soil characteristics and weather were very different in the two tests, but the major differences seemed to be in the total organic loading and in the action of algae. It was assumed during the Whittier test that a good working criterion would be 0.5 ppm of D.O. and less than 0.5 ppm of B.O.D. at the test level. The test level would of course be dependent upon the ground water level. This limit still seems to be an acceptable working rule since the sanitary quality of the Azusa effluent throughout the aerobic test averaged just a little poorer than that acceptable for drinking water. The Azusa plant effluent averaged 2.2 ppm of D.O. and 33 ppm of B.O.D. and were percolated at a rate of 0.6 cu ft per sec per acre. The Whittier waters, with 14 ppm of B.O.D. and 5.95 ppm of D.O., were spread at a rate of 0.5 cu ft per sec per acre. The organic loading at Azusa through hydraulic control averaged about twice that at Whittier. Knowing both the oxygen demand and the D.O. of the influent to the basins and the D.O. or the oxygen demand of the percolated fluid at the sampling level (or both), the approximate quantity of additional oxygen needed can be calculated. It seems probable that the permissible loading will approach a constant on all types of soil except for factors such as temperature, the action of algae in supplying extra oxygen, and the relation between the B.O.D. value and reoxygenation. The method used in these experiments to calculate the amount of oxygen supplied to the basin by the atmosphere is given here:

The amount of oxygen supplied by the atmosphere to a fluid percolated from earth basins can be estimated by difference. Thus if the oxygen demand, original D.O. of the fluid, and/or the D.O. and oxygen demand of the fluid at the testing depth is known, a calculation can be made.

Assuming no oxygen is present in the top soil and the spread fluid temperature averaged 75° F, let O.L. equal the oxygen load of the spreading basin in pounds of oxygen absorbed in 1 day by 1 wetted acre of spreading basin. Then, O.L. is the rate of percolation in millions of pounds of spread fluid per day times the quantity given by adding the 5-day B.O.D. in ppm of the spread fluid to the D.O. of the percolated fluid at the testing depth subtracting the D.O. at the inflow to the basin and also subtracting the 5-day B.O.D. in ppm of the percolated fluid at the testing depth.

Using the data obtained from the Whittier and Azusa tests, calculations of the actual amount of oxygen absorbed can be made.

	Whittier	Azusa
B.O.D. of basin influent (ppm).....	14	33
B.O.D. of fluid at 7-ft depth (ppm).....	0	1.6
D.O. of basin influent (ppm).....	4.3	2.2
D.O. of fluid at 7-ft depth (ppm).....	5.6	0.2
Percolation rate (cu ft per sec per acre)...	0.5	0.6
Percolation rate (lb per acre per day)....	2.695	3.234
Oxygen load (lb per acre per day).....	41	95

On the basis of the above figures, it is indicated that 41 lb of oxygen were supplied per wetted acre at the Whittier basin and 95 lb were supplied at the Azusa basin. The temperature and the oxygen in the soil would make some difference, but the action of algae and increased rate of reoxygenation in the higher B.O.D. Azusa waters seem to offer the most logical explanation. The Azusa tests were made when temperature and weather conditions were at an optimum for the growth of algae, while the Whittier tests were made when algae action was at a minimum. Previous experiments,^{5,6,7,8,9} as well as 24-hr D.O. tests made at Azusa (see Fig. 5) show that algae can introduce very large quantities of D.O. into waters in which they are present.

The calculation is not exact and test plots such as those described here would be desirable, if not necessary, at most locations where the spreading of treated sewage effluents is proposed. However, the calculation when used in connection with known test plot data will give an accurate estimation of the organic loading permissible at any proposed location. Thus, if the factor O.L. is calculated for a certain test plot, this value can be reinserted into the equation along with the desired standards of 0.5 ppm of D.O. and less than 0.5 ppm of B.O.D. in the percolated fluid at the test depth. The factors left to determine are the B.O.D. of the basin influent and the percolation rate. Since the influent B.O.D. is usually known, the safe percolation rate can then be calculated. Also if a limited percolation rate is possible the maximum permissible influent B.O.D. can be determined.

SOLIDS PRESENT IN THE PERCOLATED AND UNPERCOLATED EFFLUENTS

Suspended Solids.—In the Azusa test basin the secondary effluent added an average of 70 ppm of suspended solids. At the overflow end the suspended solids content had dropped to 32 ppm, and at the 2½-ft level the percolated fluid showed 9 ppm. At the 7-ft level 3 ppm of suspended solids were present during the aerobic period then when mixed primary and secondary effluents were being added and anaerobic conditions existed, the suspended solids in the

⁵ "The Role of Algae in Waste Treatment," by A. J. Espinosa, *Public Works*, Vol. 79, August, 1948, p. 36.

⁶ "Sewage Lagooning," by Jack Meyers, *Public Works*, Vol. 80, January, 1949, p. 45.

⁷ "Oxidation Ponds," Report of the Committee on Sewage Disposal, Engineering Section, American Public Health Association, *Sewage Works Journal*, Vol. 20, 1948, p. 1025.

⁸ "Sewage Oxidation Ponds—Performance Operation and Design," by D. H. Caldwell, *Sewage Works Journal*, Vol. 18, 1946, p. 433.

⁹ "Rate of Production of Oxygen by Freely Developing Algae," by W. E. Abbot, *Water and Sewage Works*, Vol. 96, 1949, p. 141.

percolated fluid at the 7-ft depth rose to 24 ppm. When aerobic conditions were re-established, the solids in the percolated samples quickly dropped to the average of 3 ppm. Illustrative of the effect of oxygen on the solids mat and thus percolation rate, is the fact that, when large quantities of air were diffused into the basin, the percolation rate increased 1 cu ft per sec per wetted acre. It seems apparent then that the maintenance of aerobic conditions is important both from the standpoint of delivering a percolated effluent of a satisfactory sanitary quality and from that of maintaining satisfactory percolation rates.

Total Solids.—The secondary plant effluent received at the test basin averaged 510 ppm total solids, and the percolated fluid at the sampling depths

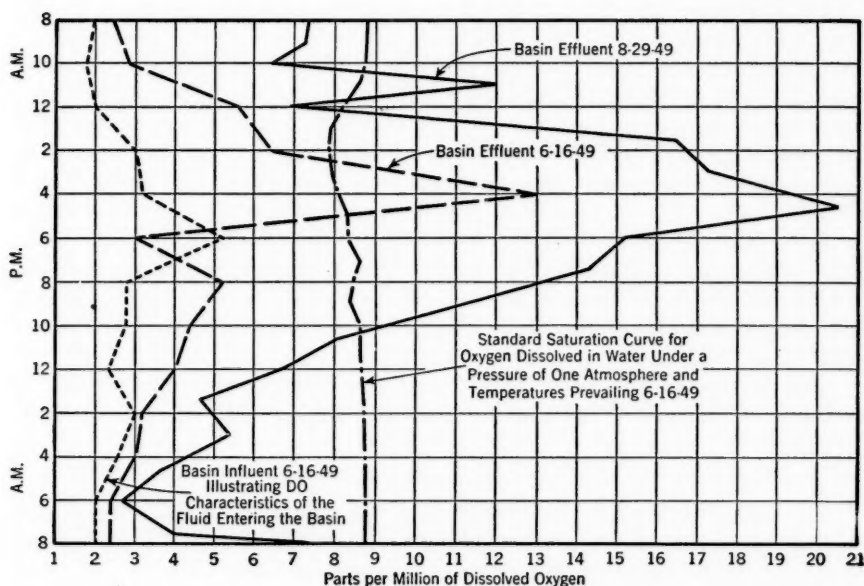


FIG. 5.—EFFECT OF ALGAE GROWTH ON D.O. CONTENT OF FLUID

averaged 435 ppm. (see Table 3). There were 3 ppm of suspended solids and 432 ppm of dissolved solids in the percolated fluid. The total and dissolved solids loading of the Azusa water supply averaged 260 ppm during the test period. A well subsequently added to the system has increased this somewhat. Thus it can be seen that there is a dissolved solids increase of 172 ppm as the water passes from a potable water supply to sewage effluent. The total dissolved solids content of the unsoftened Metropolitan Water District water is 737 ppm,¹⁰ and the upper limit for the permissible dissolved solids content of irrigation water, assuming allowable chemical characteristics, is 1,400 ppm¹¹.

¹⁰ From Table of "Chemical Analyses of Los Angeles Water—Fiscal Year 1947-48," Los Angeles Department of Water and Power, Los Angeles, Calif.

¹¹ Report Upon the Reclamation of Water from Sewage and Industrial Wastes in Los Angeles County, California, Los Angeles County Sanitation Districts, Los Angeles, Calif., April, 1949.

The Azusa sewage is representative of the domestic sewage of the Los Angeles area, so the 172 ppm pickup of dissolved solids might be considered as an average usable figure for this region. If, for example, the Azusa percolated effluent is used with 432 ppm of dissolved solids and it is assumed there is a standard pick-up of about 172 ppm of nontoxic minerals each time the water is reused, the percolated effluent must be used twice more to reach the total solids content of the Metropolitan Water District water and $3\frac{1}{2}$ times more to reach the limits for irrigation water. Rain water and ground water dilution provide an additional safety factor. Hence, it is probable that if the sanitary quality and content of undesirable minerals is controlled, treated domestic sewages similar to those reported here can be percolated into the underground with safety.

To determine the ultimate effect upon the potable water supply of the 172 ppm increment of dissolved solids, this increment must be broken down into its various components. Thus, the potable waters had 12 ppm of chlorides, and the percolated fluids had 49 ppm, or a chloride increase of 37 ppm. Table 2 shows the increase in the other critical elements. It should be noted that the amount of sodium sulfate and boron are particularly important because of their toxic effect on plants when present in high concentrations. For instance, 1.5 ppm boron, 400 ppm sulfates, and 50% sodium are the maximum limits for agricultural water. Similarly, it is desirable to maintain the carbonates and bicarbonates at less than 250 ppm. The percolated Azusa sewage could thus be reclaimed continuously through two to five cycles. In actual practice, of course, the dilution afforded by the ground waters would cut the mineral load.

The nitrate content of drinking waters is also of concern, but samples of percolated fluid showed little pickup over the original water supply content (see Table 2).

THE pH OF THE FLUIDS TESTED

The pH of the Azusa water supply was 7.5, that of the plant effluent was about 7.2, and that of the percolated fluid averaged 7.3. The pH was therefore close enough to neutral to cause little or no effect on the ground waters. The pH of the spread fluids rose as high as 8.3 when profuse light algae growths developed.

THE EFFECT OF ALGAE ON THE SPREADING OF EFFLUENT

Algae will grow in an aerobic fluid when sunshine is present and temperature conditions are favorable. They are particularly sensitive to temperature,⁸ so the Whittier basin, operating during the winter, received very little oxygen from the action of algae, while the Azusa basin received large quantities of oxygen. The algae supply oxygen to the fluids they grow in as a result of their life processes, wherein carbon dioxide is synthesized to starch, using chlorophyll and sunlight, and oxygen is liberated as a by-product.

In the experiment, the algae seemed to have little effect on the coli-aerogenes count of the fluid in the percolation bed, but the D.O. they produced helped satisfy the B.O.D. and maintain aerobic conditions.

Since the algae obtain their energy from the sunlight, the D.O. they produce follows a characteristic 24-hr curve, and they are usually not effective at fluid depths of over 2 ft.⁷ Therefore, although the algae do contribute organic matter to the basin, the amount of D.O. they produce makes their presence in percolation beds for sewage effluents quite desirable. These algae may also appear unsightly.

TEMPERATURE AND WEATHER DATA

Between May 13, 1949, and June 30, 1949, the temperature of the fluid in the Azusa basin ranged from 60° F to 83° F. Later the water temperatures averaged 89° F. Thus, maximum warm conditions were approximated in the spreading basin. The warm weather did not create any odor problem although the one week period during which 100 ppm. B.O.D. fluid was spread and no D.O. existed there were slight odors.

It is probable that as long as aerobic conditions are maintained in the basins and no noxious chemical wastes are allowed, serious odor problems will not be encountered.

The experimental data obtained in the Azusa experiment is summarized in Table 3 and in Fig. 4.

THE CONSERVATION OF FERTILIZER VALUES

The data obtained was not sufficient to allow valid conclusions on this point. The spread effluents averaged about 30 ppm of organic nitrogen, and percolated fluids showed about 7 ppm of nitrate nitrogen. However, the sludge that collects on the floor of the spreading basin contains 3.1% of organic nitrogen and can be collected by scraping.

CONCLUSIONS

1. A method for successfully collecting percolated fluid samples from the subsoils was developed. Collection pans buried within the spreading grounds successfully carried the percolated fluid into a sampling well.

2. It was found that it is possible to satisfactorily percolate sewage effluents at rates as high as 0.6 cu ft per sec per acre for periods of several months. Initially very high percolation rates are obtainable in coarse soils but the bed will eventually seal off and the rates approach 0.2 cu ft per sec per acre. Within the limits of the rates used in these tests and dependent upon an adequate distance between the basin and the ground water level, initial percolation rates on porous soils are controlled by the depth of the fluid in the basin; after continuous spreading an impervious mat builds up on the surface of the coarse soil and the fluid depth has little effect reacting the same as a fine soil. Even when aerobic conditions are present, the percolation rate gradually decreases, and the bed must be dried and cultivated. The actual operating schedule must be decided by the local conditions.

3. No coli-aerogenes pollution resulted when aerobic conditions were maintained in the percolated fluid. Conversely anaerobic conditions allowed the bacteria to penetrate to at least 7 ft into the ground.

4. Bacteriological examination of the soil beneath the test spreading beds seemed to confirm the assumption that bacterial pollution was carried by fluids percolated under anaerobic conditions.

5. Experience at the Whittier and Azusa test basins indicates that if the arbitrarily determined standard of 0.5 ppm of D.O. and less than 0.5 ppm of B.O.D. in the percolated fluid at the testing depth is maintained, water of a satisfactory sanitary quality can be produced.

6. The organic loading placed on the basin by the spread fluid is determined by the D.O., B.O.D., and percolation rate. Hence, initial high percolation rates must be carefully evaluated when spreading on coarse soils. It seems probable that the permissible organic loading on any soil approaches a constant that can be calculated but that the large amounts of D.O. contributed by algae can cause variation. Safe practice would be to apply a base loading such as obtained in the winter when algae are not active. In these experiments this was calculated to be 40 lbs of B.O.D. per wetted acre per day.

7. The physical characteristics of the soil in the percolation basins are of some importance in the process, so the depth of soil above the water table should be evaluated. However, water of good quality was produced at the 7-ft depth in both the tight Whittier soil and loose Azusa soil. Impervious soils obviously cannot be used for percolation basins.

8. If the basin was kept in an aerobic condition, the suspended solids of the spread fluid had little effect on the operation and were rapidly oxidized. If the organic loading increased and anaerobic conditions prevailed, the basin was rapidly sealed off and percolation rates decreased. Odor difficulties did not occur if aerobic conditions were maintained although basin temperatures reached 89° F.

9. It was found that the dissolved solids increment in the cycle connecting potable water to secondary sewage effluent at the Azusa plant was 172 ppm. It was also suggested that this be considered as normal for domestic sewages of the Southern California area. Such a pickup would allow the water to be used continuously two to five times unless undesirable wastes were not permitted in the sewers. The Azusa effluent showed a pickup of 23 ppm of sulfates, 30 ppm of chlorides, 14% sodium, and 0.1 ppm of boron per single use cycle and could, therefore, be used as suggested. Rain and ground water provide a dilution factor for the reclaimed sewage.

10. No odor problems appeared, although fluid temperatures ranging from 67° F to 89° F were found. However, the basins were somewhat unsightly in appearance because of the profuse algae growths. The percolated fluids were sparkling clear as long as aerobic conditions were maintained.

ACKNOWLEDGEMENTS

As officials of the Los Angeles County Flood Control District, H. E. Hedger and Paul Bauman, Members, ASCE, authorized the sewage reclamation tests at Whittier and Azusa. Finley B. Lavery, M. ASCE, handled the general direction of the reclamation test program, and L. W. Jordan, Assoc. M. ASCE, was the immediate supervisor of the work in the field. A. M. Rawn, M. ASCE, acting for the Los Angeles County Sanitation Districts, authorized the chemical and bacterial testing that was necessary.

CURRENT PAPERS AND DISCUSSIONS

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